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RESEARCH MEMORANDUM

COMPARATIVE DRAG MEASUREMENTS AT TRANSONIC SPEEDS OF 6-PERCENT-THICK AIRFOILS OF SYMMETRICAL DOUBLE-WEDGE AND CIRCULAR-ARC SECTIONS FROM TESTS BY THE NACA WING-FLOW METHOD

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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COMPARATIVE DRAG MEASUREMENTS AT TRANSONIC SPEEDS OF 6-PERCENT-THICK AIRFOILS OF SYMMETRICAL DOUBLE-WEDGE AND CIRCULAR-ARC SECTIONS FROM TESTS BY THE NACA WING-FLOW METHOD

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SUMMARY

Comparative drag measurements at zero lift have been obtained at transonic speeds for two sharp-leading-edge airfoils by the NACA wing-flow method. One airfoil had a symmetrical circular-arc section and the other had a symmetrical double-wedge section. Both airfoils had a thickness of 6 percent of the chord, were of rectangular plan form, and had an aspect ratio of 4.0. The tests covered a Mach number range of 0.65 to 1.10.

The results indicated that the principal difference in the drag characteristics of the two airfoils at zero lift is the earlier drag rise of the double-wedge section. Although the double-wedge airfoil had a somewhat higher drag throughout the Mach number range tested, the difference decreased with increasing Mach number after the onset of the drag rise of the circular-arc section, and at the highest Mach number attained, 1.10, the drag coefficient for the two airfoils was about the same.

INTRODUCTION

As part of an extensive research program being conducted by the NACA to determine the suitability of various airfoil sections for controllable flights through the transonic and into the supersonic speed range, two sharp-leading-edge airfoils have been tested in the transonic speed range by the NACA wing-flow method. One airfoil had a symmetrical circular-arc section and the other had a symmetrical double-wedge section. The measurements included: normal force, chord force, and pitching moment at various angles of attack. Mach numbers [redacted]anged from 0.65 to 1.10.

Although results of the tests are not as yet completely evaluated, sufficient data are available to permit a comparison of the drag at zero lift of the two airfoils. These data are presented herein.

APPARATUS, METHODS, AND TESTS

The test procedure and equipment were essentially the same as those for previous wing-flow tests of airfoils as described in references 1 and 2. The arrangement and dimensions of the two models are shown in figure 1. One of the models had a symmetrical circular-arc section and the other had a symmetrical double-wedge section. Otherwise the model dimensions were the same with a thickness of 6 percent, a rectangular plan form, and an aspect ratio of 4.0, considering the airplane wing as a reflection plane. The airfoils were mounted above the wing of the airplane with a circular end plate attached to the end of the airfoil adjacent to the wing surface, as indicated in figure 2. Although special tests were made to determine the tare drag of the end plate, the correction was not completely established and is not applied to the data presented herein. The chordwise velocity gradients in the test region on the airplane wing as determined from static-pressure measurements at the wing surface with the model off are indicated in figure 3. The effect of these gradients is not known; therefore, no correction has been attempted. However, velocities measured at the wing surface have been corrected by a factor of 0.98, as determined from special tests, to account for the decrease in velocity with distance from the wing surface.

Three tests of each airfoil were made in high-speed dives to obtain a range of Reynolds number independent of Mach number. The first dive covered an altitude range from 28,000 to 22,000 feet, the second from 18,000 to 12,000 feet, and the third dive from 12,000 to 6000 feet.

RESULTS AND DISCUSSION

The drag coefficients at zero lift of the airfoils with double-wedge and circular-arc sections are plotted against Mach number in figures 4(a) and 4(b), respectively, for each of the three tests. The variation of Reynolds number with Mach number for the three tests is shown in figure 4(c). It is indicated by the test points of figures 4(a) and 4(b) that any effect on the drag due to the differences in Reynolds numbers for the three tests is within the experimental accuracy.

The absolute values of drag coefficients in figures 4(a) and 4(b) are too high, due to the drag of the end plate. It was indicated from the special tests previously mentioned that the drag coefficient of the end plate might be of the order of 0.07 based on the area of the models. It appeared, however, that the drag coefficient of the end plate was relatively constant over the Mach number range and hence would be expected to have little effect on the variation of drag coefficient with Mach number shown for the airfoils.

The drag coefficients shown in figures 4(a) and 4(b) are plotted together for comparison in figure 5. The principal difference in drag characteristics of the two airfoils is the earlier drag rise with the double-wedge section which occurs at a Mach number of about 0.78 as compared to 0.85 with the circular-arc airfoil. The drag reaches a maximum at about the same Mach number, 0.99, for both airfoils. The double-wedge airfoil has a somewhat higher drag throughout the Mach number range tested, but the difference decreases with increasing Mach number after the onset of the drag rise of the circular-arc section. At the highest Mach number attained, 1.10, the drag coefficient of the two airfoils is about the same.

The results of drag tests of a symmetrical circular-arc section obtained by the free-fall method (reference 3) and by tests in the Langley rectangular high-speed tunnel (reference 4), and results of drag tests of a double-wedge section obtained in the Ames 1- by $3\frac{1}{2}$-foot high-speed tunnel (unpublished data), are also shown for comparison in figure 5. The results of the free-fall tests of the circular-arc section show close agreement with the present tests with regard to the magnitude of the drag rise and the Mach numbers at which the drag break, and the maximum drag coefficient occur. The difference in absolute magnitude of the drag coefficients of the present tests and the free-fall test is probably mainly due to the drag of the end plate used in the present investigation. The results of the wind-tunnel tests agree with the present tests in that the start of the drag rise with the double-wedge airfoil occurs at a substantially lower Mach number than with the airfoil of circular-arc section. The wind-tunnel tests show a somewhat earlier and steeper drag rise than is indicated by the present investigation. The results of reference 5 show that these differences would be expected because of the different aspect ratios used for the wind-tunnel and wing-flow tests.

CONCLUSIONS

The results of comparative drag tests at zero lift on airfoils with a symmetrical double-wedge section and a symmetrical circular-arc section indicate that the principal difference in the drag characteristics of the two airfoils is the earlier drag rise with the double-wedge section. Although the double-wedge airfoil had a somewhat higher drag throughout the Mach number range tested, the difference decreased with increasing Mach number after the onset of the drag rise of the circular-arc section, and at the highest Mach number attained, 1.10, the drag coefficient for the two airfoils was about the same.

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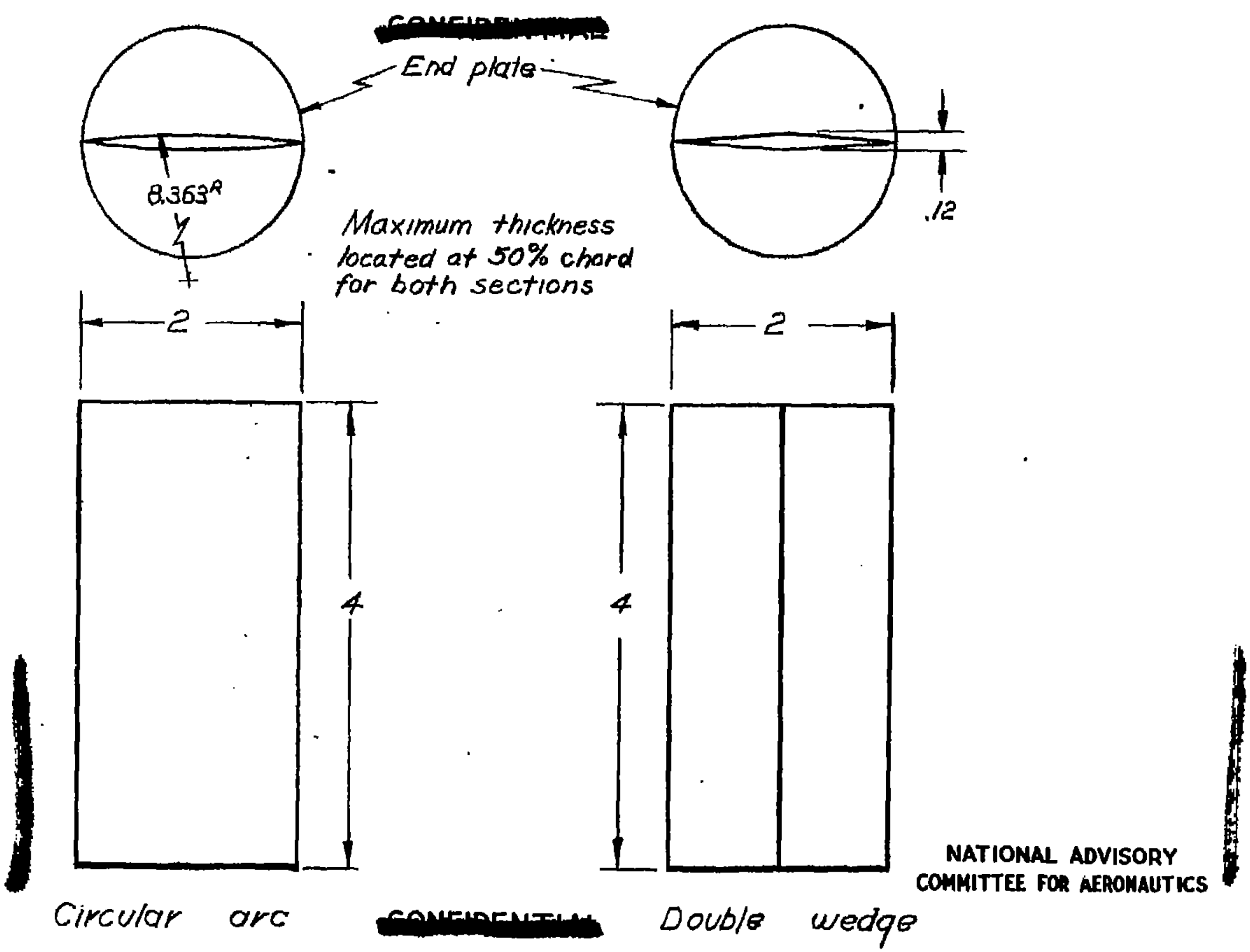


[redacted]

Figure 1.- Sketch of airfoils tested. All dimensions in inches.

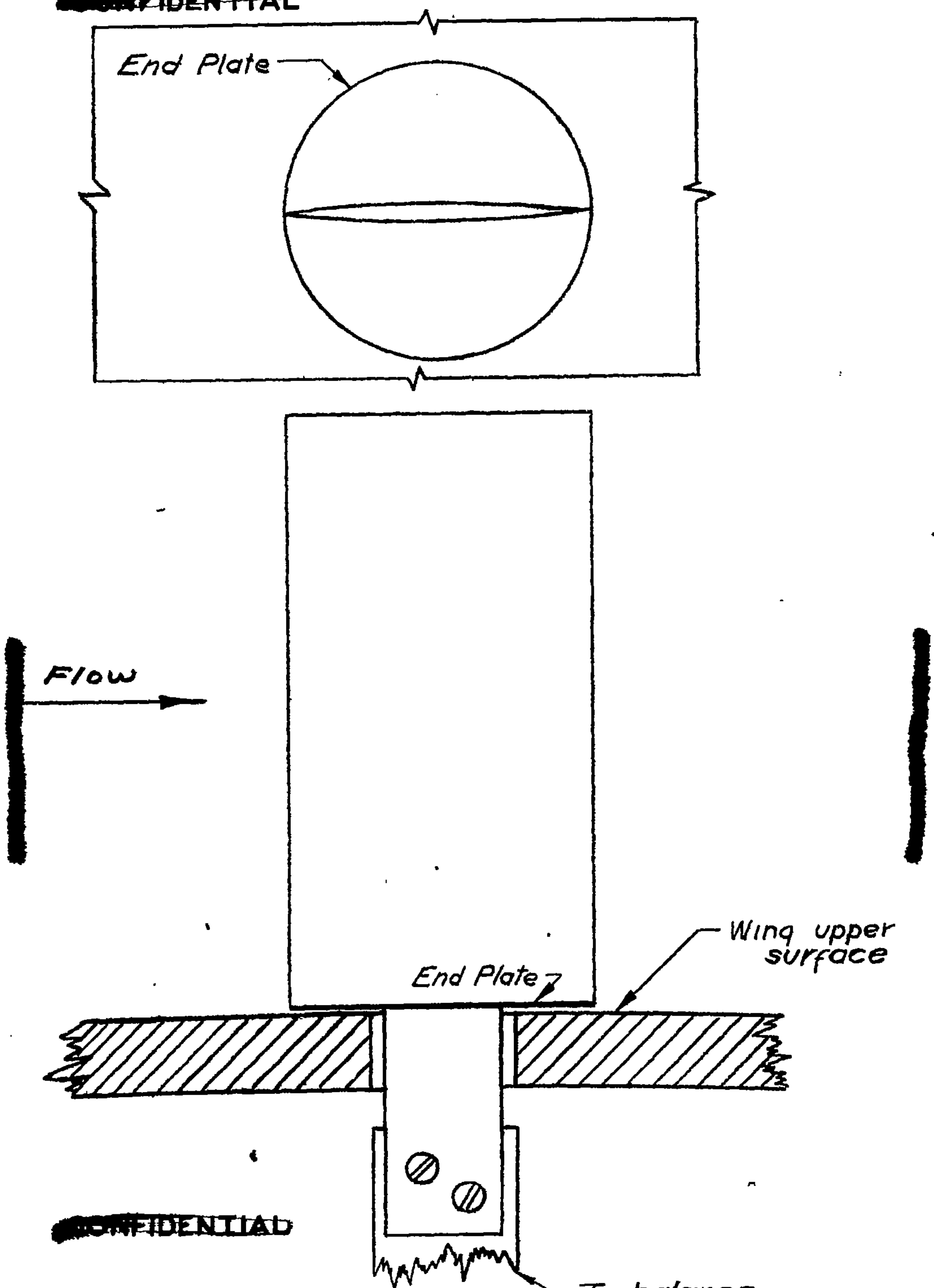


Figure 2.- Detail of mounting sharp- **leading** -edge airfoil on airplane wing.

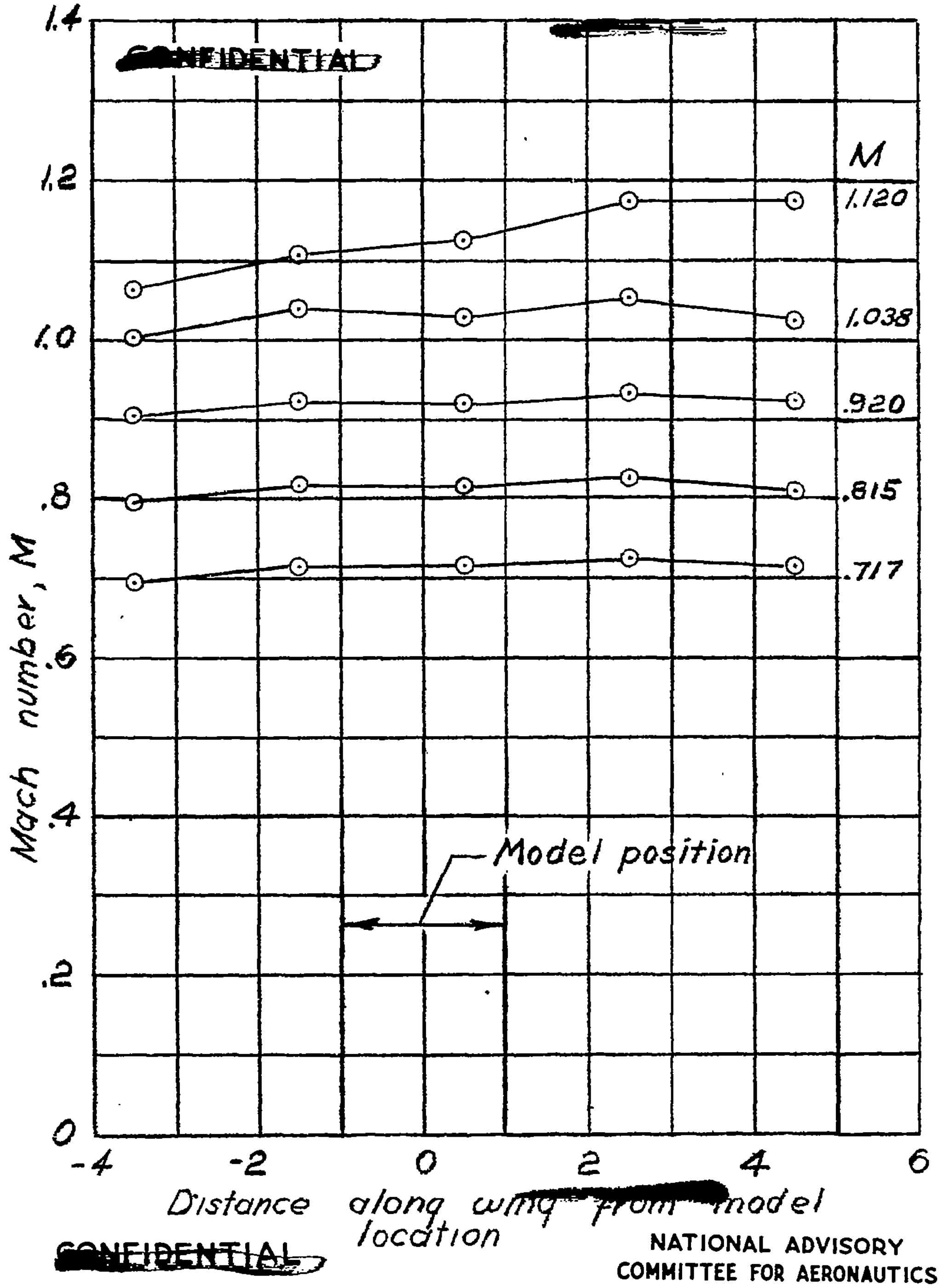


Figure 3.- Typical chordwise variation of Mach number in the test region on the airplane wing for several Mach numbers at the model station.

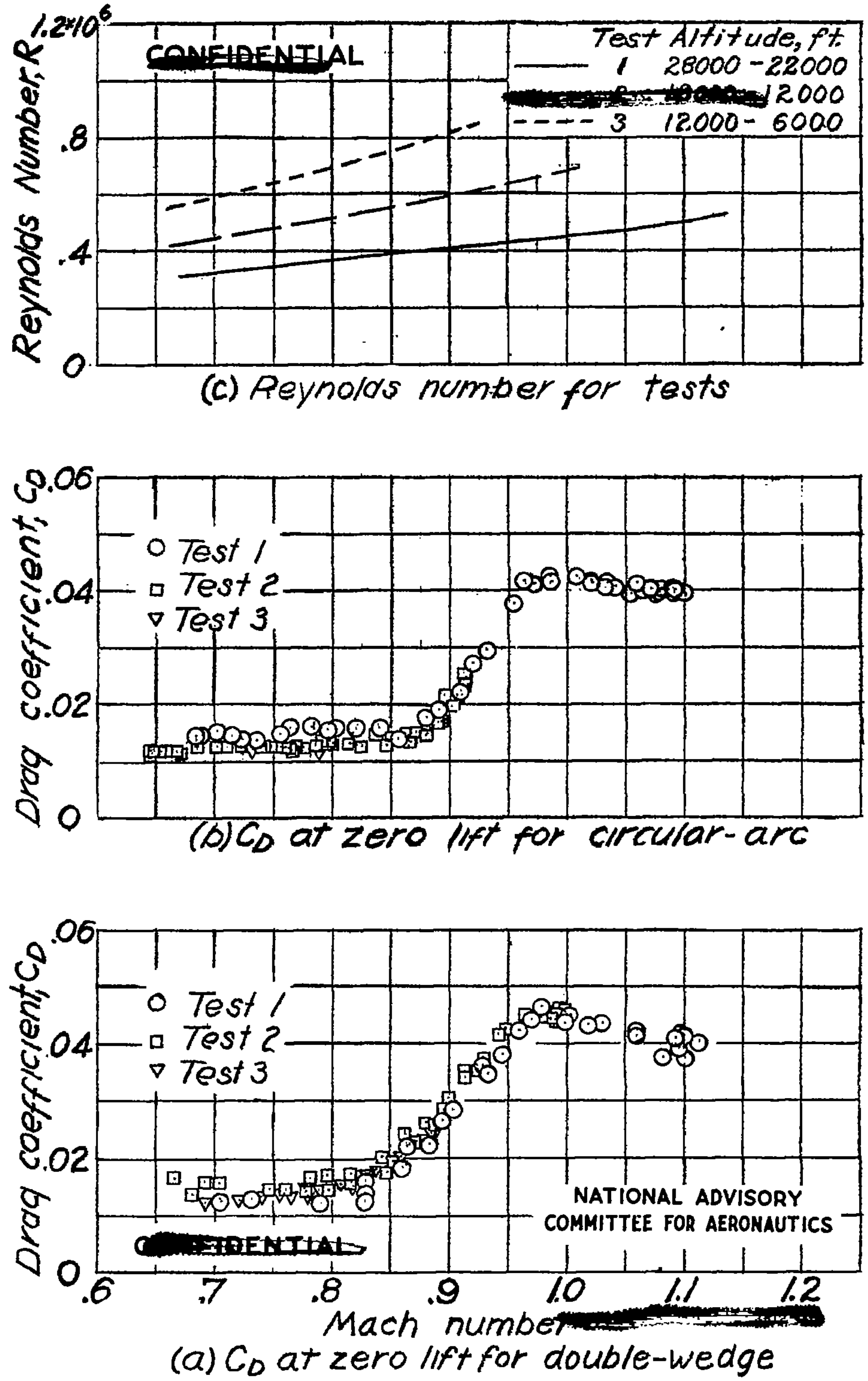
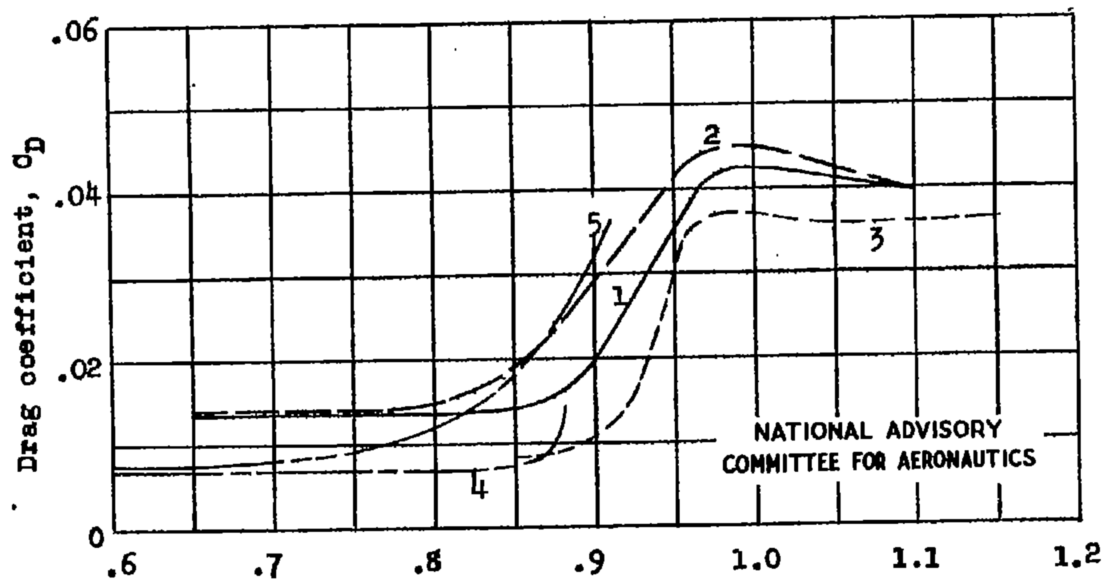


Figure 4.- Variation of drag coefficient for zero lift and Reynolds number with Mach number for airfoils with 6 percent thick circular-arc and double-wedge airfoil sections.

[redacted]

Symbol	Airfoil	Aspect Ratio	Reynolds Numbers	Test Method	Reference
1 ————	circular-arc	4.0	$.31\times10^6$ - $.85\times10^6$	Wing-Flow	Present Tests
2 — — —	double-wedge	4.0	$.31\times10^6$ - $.85\times10^6$	Wing-Flow	Present Tests
3 - - - - - -	circular-arc	7.6	1.6×10^6 - 5.0×10^6	Free-Fall	3
4 ——- - -	circular-arc	∞	$.5\times10^6$ - 1.0×10^6	Langley RHST	4
5 —— - - ——	double-wedge	∞	1.0×10^6 - 2.0×10^6	AAL 1- by 3½-foot HST	5



[redacted]

Figure 5.- Comparison of variation of drag coefficient at zero lift with Mach number for 6-percent thick circular-arc and double-wedge airfoil sections tested by different methods.